Eötvös Loránd University, Faculty of Education and Psychology

THESES OF THE DOCTORAL DISSERTATION

ANETT RAGÓ

The dynamics of conceptual development

- event and categorization in early childhood, in case of artificial concepts

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Introduction

The general theoretical problem which is that basis of my dissertation is a more precise understanding of processes behind *domain-specific concept organisation.*

Maintenance of super-ordinate category-boundaries (animate and inanimate, animal, vehicle, furniture, etc.) can be observed even in *early childhood*. Children can be easily confused in their categorical decisions, but they are sensitive to the borders of bigger ontological categories.

The early effective observation of super-ordinate category-boundaries is an important question, for early high level (abstract) stimulus organisation could refer to the possibility that conceptual knowledge holds „pre-wired", even inborn modules, structures or possibly contents.

Recent infant- and child studies appear to support the assumption, that the basis of adult domain-specific knowledge-organisation is early analytical object-recognition and information-processing. Children are sensitive to the structural differences of opposing categories even in the beginning of development. They keep the results of these discriminations for a set time and build expectations towards the behaviour of the outside worlds' objects. The appearance of super-ordinate category in early infanthood was proved by Mandler and colleagues (1996; Mandler & McDonough, 1993, 1996, 2000) as well as others. In opposition of them, however, most stress the emersion of super-ordinate category-boundaries. Fenson and colleagues (1988) studied 26 months old children with matching, while they varied the super-ordinate categories' general similarities. The results supported, that super-ordinate discrimination only appears when the categories are similar. More recently Bornstein and Arterberry's (2010) study confirmed that, without perceptual similarity, neither higher nor basic level categorization behavior can be detected. Even more so, super-ordinate similarity is more inclusive than basic level (see Tversky, 1989).

In the studies of Paul Quinn and colleagues successfully showed what could possibly cause the early emergence of super-ordinate categories knowledge (Behl-Chada, 1996; Quinn et. al, 2006; Quinn & Johnson, 1997). Their results suggest that the formation of super-ordinate

category-representation precedes basic level (it can be detected at 2 months of age) however the reason behind this should be found *in the structure of the stimulus* and does not require abstract conceptual. Quinn and Johnson's (1997, 2000) connectionist model showed that in super-ordinates, the geometric features of stimulus is similar, and connected to the general learning processes, leads to successful categorization behaviour as well as category-level mental organization. Their results also showed how the number of stimulus introduced (the growth of knowledge) influenced discrimination, starting for the emersion of global features gradually moving to the detection of detailed differences.

The other line of reasons against a dual system is the basic level categories early organization. The arguments are believable because, they didn't only just show, that infant are sensitive to highlighting similar features at 2 months of age, are able to abstract them, and so are capable of creating simple categories, but also that all that is needed is the operation of the perceptual system. Paul Quinn and his research group proved in a number of experiments the existence of early infant categorization ability. In their experiments, they detected that infants are capable of devise basic level categories as early as 3-4 months of age (from the dog and cat categories the bird category separates), meaning they are capable of managing different, more or less heterogenic conspecifics as similar, by highlighting the general features (Quinn et. al, 1993; Quinn & Eimas, 1996).

These early categories are naturally simple, unstructured and quite unstable. Moreover they are dependent on their presentation and the homogeneity of categories. Despite all of this, they show that the category-boundaries present in adulthood are grounded quite early. It strengthens the view that the *qualitative changes* observable during *development* is a result of mostly *growth in knowledge* and not the application of a different categorization strategy.

The first assessment series I have designed have direct reference to Quinn and colleagues' (Quinn & Eimas, 1996; Spencer et. al, 1997; Quinn et. al, 2001, 2009) results. Their experiments systematically investigated infants' early perceptual categorisation behaviour. They asked whether the structural processing of stimuli appeared at this age as well. Their results uniformly show the importance of head area even at this age. The experiments didn't explain whether this answer-tendency could be seen as a specific categorization strategy (*domain-specific* answer) or in every case the given category-contrast appoints the area of similarity, and the participants pay attention to actually salient feature (a categorization principle called *specific strategy* by me). The question in regards to development is

important because, first of all, it could help identify a specific categorization strategy, with which children would be able to successfully separate animate and inanimate categories. Second of all, however, we have to presume, that the animate and inanimate categories' boundaries separate according to super-ordinate categories during an encounter the stimuli (and the systematic reaction to differences) influenced by the systematic differences between stimuli.

In Quinn and Eimas' (1996) experiment they tested 3 and 4 month old infants' early categorization behaviour. In this case as well 2 closely related (dog and cat) basic level category discrimination was the task, in a familiarization-novelty preferences situation. In this experiment, however, they investigated if, when looking at colour photos, the information of head and body is enough information for a successful categorization. Their results were positive in regards to full body pictures as well as head pictures, while in the 'only body' condition their results were negative, meaning they found that the area of the head, the face region mostly, was enough for discrimination. Adult control results imply that adults are capable of identify categories based on body alone.

The prominence of the head area can only be proven with real contrast conditions. In their further studies the authors (Spencer et. al, 1997) created dog-cat hybrids. These were full body pictures, where the hybrids were made up by one category's member's body and the other category's member's head. In this experiment adult controls were included as well, where they were asked to judge the pictures typicality as well as examined them in decision-making situations, timing their reaction-times. The results showed uniformly the *priority of head information*, even in the case of adult despite the fact that they processed the body's information just as clearly, but decisions made based on head information was quicker to do. This result supports Morton and Johnson's (1991) assumption which outlines a 2-way developmental process. Their basic proposition is that the area of the face is prominent from birth for infants. The essence of the so-called "*structural hypothesis*" is that, preference for face information is not a feature of a general perceptual system, but formed because of a congenital specific sensitivity to the structures of other conspecifics' faces (CONSPEC). Later, with the growth of experience (according to the model, from 2 months of age) beside this specific system a general learning mechanism activates as well (CONLEARN) which, underpinned by the previous specificity, collects and stores information about the face.

If we take into account the above mentioned theory in regards to Quinn and colleagues' findings, then it can be said that preference for the head area can be interpreted as domain-specific. Since in the case of adults the situation was similar, a possibility could emerge that this early sensitivity remains in regards to animate objects (here it probably the influence of experience gathered through CONLEARN).

The newer results Quinn and colleagues' (2001) experiments however contradict this assumption. Using dog and cat silhouette pictures, they detected that the contour of the head (without the information of face) is enough to create category-representations. Once again they did looking preferences with 3-4 months old infants, which resulted in head preference in this case as well. According to the authors interpretation this does not necessarily oppose the Morton and Johnson model, provided the authors rewrite it (correcting it to head and not face priority). But it could also naturally be, that a *domain-general categorization mechanism* is running in these situations that focuses on the most discriminating part of the given stimuli-contrast, which would be, in case of a close and similar dog-cat stimuli pair, the area of the head.

Quinn and colleagues' newest, once again using dog and cat stimuli, looking preferences experiment using 6-7 month old infants supports the previous findings (Quinn et. al, 2009). The strength of the experiment, besides testing the applicability of the new method, had been to show, that children really did look at the head area, irrelevant of its spatial situation (up or down). They used colour pictures in this experiment. A further peculiarity of the results, is that with the help of this method, the perceptual proportions of the head/body correspond with the given area looking differences. The answer is an unambiguous no: the participants looked at the head area much more than they did at the body. So, the head area got a too much attention given its size!

So the two basic level category-contrast results show systematic structural processing in case of infants. The outstanding role of the head area verifies the assumption that small children also process object information analytically (as well as according to contrast). The experiments don't verify the domain-specific feature of head based decision-making, to do so different aspect contrasts are needed as well the involvement of other age groups too.

General research questions and principles

The studies explained in the introduction investigated the exploration of the nature of background processes involved in categorization behaviour. These results are in parallel with the dynamical theoretical approach. To stress that the importance of research is not on the content of categories but the more precise understanding of processes involved in knowledge organisation.

The appearance of the used stimulus, the presentation of it, the chosen test method, the expectations of participants all played an important part in the formation of results.

1. How big of a part did concrete information (the contrast defined by the task) in the categorization behaviour? How does the concrete choice reflect on the participants' categorization structure?

Because of the regularity of categorization behaviour and the existence of perceptual categories in infanthood implicate that the basis of domain-specific knowledge organisation is the result of the early cognitive systems' attention mechanism to analytical, in the case of certain contrasts outstanding, or more commonly diagnostical object-features, I investigate the following question with my research:

2. What kind of categorization strategies can we observe in child- and adulthood? Can the appearance of categorization principles supportive of domain-specific processing in the categorization behaviour of kindergarteners be demonstrable? What does information-growth during development mean in terms of categorization strategies?

The question of knowledge organisation isn't only interesting in a developmental sense, and because of this, the third group of questions is in regards to the function of processing systems influencing the organisation of new information:

3. In what form does rule-learning appear in case of complex, everyday stimulus? How could explicit and implicit processing work together in representing and long term recalling of abstract relations?

The similarity of these studies is the use of *artificial stimuli*. The aim of this was to somehow create a novel situation during the experiment, and thus control the knowledge frame activated by the participants. In all cases, these novel stimuli possess complex perceptual structure, the aim of this being to model the everyday categorization processes. But because

in every case during analysis I investigated the appearance of structural response types, I wished to control frame of information accessible by the participants.

Research situations focusing on developmental and individual information-growth not only differentiate strongly in methodology, but also in regards to concepts used in the referenced literature as well as their definitions.

Despite all of this I believe it is important to connect these two research areas, since in my opinion these above described and studied problems relate with the matter of organization of conceptual representations.

Study 1.

As a starting experiment, I tested the mechanism of classification of *basic level categories*. My aim had been to create such stimuli, which would successfully activate basic level categorical knowledge. I designed such a *visual-experimental situation*, that each '*specimen*' not only has features of the basic level category, but was also *unique*, meaning they are clearly distinguishable and *varied*. My question was, how much difference can be found between the two *developmental* groups according to how much they relate to the given stimulus' actual organization as well as which *stimulus-features* they base their decisions on.

I also wanted to investigate whether the structural processing of the stimuli is present in early childhood – that is, if children *separate specific stimuli-details*, which they base their decisions upon.

The stimuli created by myself were *silhouettes*, preserving the contours of the objects, presumably retaining the basic-level category information as well. Furthermore, because I was designing behavioural studies, it was important for me to be able to separate certain structural details in the participants' choices. For this reason, I created *hybrid specimen* – which became the experiments' test subjects – by mixing up the basic categories' heads and bodies.

Primarily I designed a *forced choice* experiment, however to accurately understand the results, further control experiments were required. The *pair-wise comparison* situation models free classification, where participants are allowed to decide the terms of assignments into group. An otherwise hard to control and interpret experimental situation appeared to have been useful, for it gave information regarding the general similarity of stimuli, in light of which a couple of doubtful results became interpretable. I was only able to use *eye-tracking method* in case of the adult participants, though these results help in the interpretation of developmental data as well. This relatively new experimental approach uncovers a lot about the use of categorization strategies as well as this way helping us to better understand behavioural results.

My starting point had been that observation of categorization strategies in early child- and adulthood would allow of *definition of characteristics of developmental changes*.

Further peculiarity of my research is that it *extends the range of examined categories* compared to reference tests. The use of '*animate*' *categories* is intended to measure the

possibility of extending head-based choices, while the introduction of *animate-inanimate category-contrast* is intended to measure the influence of *super-ordinate category information* on the organization of objects, which are different on basic levels.

Hypotheses

1. Testing of dominance of head area

a. Categorical decisions based on the head of the image will appear as a clear strategy in case of the dog-cat category pair.

b. If the head-based categorical decision is a domain-specific categorization tendency in case of animate object, then it will be observed in case of the *fish-bird* category pair as well. If it's *domain-general, but specific, if the strategy is directed towards salient features*, then it will appear only in case of contrasts where the head is the most discriminating (*'principle of salient specific feature'*). In this case, in case of the fish-bird category pair, we expect body based categorization (does the image have feet or not).

c. By comparing *animate and inanimate* objects the contrast of two main ontological areas is created as well. This is assumed to result in *categorization strategy-shift* in case of bird-airplane and fish-airplane category pairs. If participants are *sensitive the boundary between animate and inanimate*, then they will use a *different* strategy from before in case of the hybrids. However, if they depend on the actual stimulus-organization in case of animate-inanimate category contrasts as well, then they will use specific, trait strategy. Because the hybrids created this way are in all cases *novel stimuli* (or at least unusual), it is also possible, that participants will use a *non-specific categorization strategy*, and base their decisions on the bigger surface (body depended categorical decision). However, if the hybrid is a more plausible specimen of one category, then it is possible that we will observe 'one-dimensional' decision (the hybrids will belong to one category).

2. Developmental changes

Based on data collected from literature we expect a *qualitative shift* in decisions from both kindergarteners' as well as adults' categorization behaviour. This will probably manifest in case of the animate-inanimate contrast, in such that, while at the appearance of the inanimate category a clear strategy shift will be observable in case of adults, children will probably prefer categorization principle used beforehand.

3. Effect of designation

Because designation involves labelling, it goes along with a selective, shifting towards general features, emphasizing of the given object's features, and as such we expect *the advancing of designation condition to change the adult participants' answers*. Since after the process of labelling subjects should remember all of the labels they gave, we do not expect advance designation to influence kindergarteners' force choice strategies.

Results

In the following paragraphs I will shortly summarise and interpret the result in relation to each hypothesis.

1. Strategies of emphasising structural stimuli features

a. The results were straightforward in ways that adult categorised hybrids based on the head of the image. The responses stayed stable despite of the variability of unique features. Accordingly, in case of the dog-cat category pair, the observed *head-preference is a systematic categorization strategy*.

b. Adults only used the head based strategy in case of the dag-cat category pair. The other animate-animate category pair (fish-bird) they decided based on the *principle of salient specific feature*, meaning they used one *specific strategy*, oriented to the general structural features of the given category-contrast. Consequently *the observed head-preference in case of the dog-cat category pair* cannot be seen as *domain-specific* categorization strategy in their case.

c. The adults' categorization strategy is systematic in this instance as well, but was different in case of animate categories. In both category-contrasts they made decisions about the membership of categories depending on the body.

Based on the answers of categorization of adults' we can assume that they are able to handle the *basic level category boundaries flexibly*, and are capable of classifying *new or strange* stimuli based on *pre-existing categories*. *They don't employ specific strategies*, but react to the disposition of the given category-contrast based on known categories. They make an effort to use *uniform categorization strategies,* which suggest that categorical thinking is important for them.

The second hypothesis assumed there were *changes* observable in the course of *development*.

2. The results show differing categorization *strategy-application* in case of kindergarteners and adults, which suggest knowledge growth during development results in qualitative changes.

A systematic categorization choice characterises kindergarteners' answers as well, though in general their decisions were less uniform on a group level. General feature was the higher

proportion of head based choices. The reason of uncertainty was in part the semantic contrast of hybrid specimen (they mean two things at once), and in part the more typical tendency of their answers – a heightened observance of unique traits of a given stimulus organization.

a–b. In case of the dog-cat category pair head based decision appear, similarly to adults. Because the judgement of this category didn't change during development, it can be assumed that *early perceptual categories* constitute a *foundation for adult categories* in this instant, especially in cases where differences between categories can be structurally grasped even at basic level.

Kindergarteners see head information as relevant during the categorization behaviour. However, because mostly head based decisions appeared in the other two category contrasts as well, and the results of the eye movement tracking experiments showed that area of the head of the image was generally used information during recognition, I reached the conclusion that *head based categorization could be a generally applicable, structural categorization principle*, meaning children base their decision about category membership on information about the head of a figure. It would appear, that they *generalise the principle used in identification to categorization situation*. This supposedly doesn't cause any problems in everyday life, since contradicting information is rare, but it was detected in the experimental situation.

c. In case of the two animate-inanimate category pair kindergarteners' appeared to have used the same strategies as adults, since they based their decisions on the *body area* in case of the bird-airplane category pair, while they used a *specific strategy* in regards to the fish-airplane category pair. However their choices have another peculiarity: I refer to it as *one-dimensional*, basically because the children categorise the *contradictory hybrids* based on one aspect.

Based on the results I concluded that for kindergarteners, the contradictoriness of the hybrid specimen, which in essence is dual category information, caused problems in their categorization decisions. In case of animate-animate category contrast, taking into consideration the head information was the specific strategy, while in case of animate-inanimate contrast, probably because of the general similar organisation of stimuli, the bigger area (body) information was the basis for decision. It's been shown that the acceptance of competing meanings of an ambiguous figure causes problems for

kindergarteners (see Beck et. al, 2011), which, in this case could not be overwritten by general knowledge categories.

I have divided the changes observed during development, as in the difference between the two developmental groups' categorization behaviour into two parts before. On one hand, development is about categorization behaviour becoming flexible, which is possible because people are able to depend more reliably on pre-existing categorical information. Other characteristic difference is the consideration for super ordinate categories – while adults treated animate-inanimate categories uniformly, kindergarteners didn't take into account the similarities of the contrast in their decisions.

The third hypothesis concerned the detection of linguistic effects in regards to testing the *influence of labelling*. The assumption was that the detection condition would affect the adults' responses.

3. The designation condition did in fact *affect* the adults' response furthermore the results allow us to make further assumptions as well.

A more precise analysis of the results, which included i), the analysis of strategy applied when *designating hybrids*, ii), the verification in *pair-wise comparison* situations of the fish-bird hybrids' *salient* being, and finally iii), in the analysis of *eye-tracking* results, the discovery of *different strategies* assigned by the labelling and viewing time showed that designation *strengthens the discrimination between stimuli*.

The *designation* task in this instance highlighted the atypicality of hybrids differing significantly from normal category members, which pushed the answers towards *general similarity decisions*. Further peculiarity of the results is that in case of the three other category pair, *labelling strengthened* the *categorization strategy* used earlier, which could suggest, that the previous strategy-choice adapted *to already present category-boundaries*.

The kindergarteners' categorization strategies were not influenced by the labelling condition demonstrably, however the analysis of structural differences between the two conditions strengthen the conclusions based on the results obtained from adults.

Therefore, designation is a robust *discrimination* task, which prompts the respondent to *highlight the differences* between given stimuli. This supports results from previous studies (Markman, 1989). The experiment also support, that linguistic label directs attention to the discovery of "whole objects" type differences (see Yamauchi & Markman, 2004).

Study 2

The experimental design of *perceptual category-learning* exercises is teaching participants to classify a given stimuli. During learning the participants receive *feedback*. Their knowledge is then tested in a new a situation or with the help of new stimuli. The type of task is defined by the characteristics of the stimuli, the features of stimuli used during learning, the time and form of feedback as well as the features of specimen given in the tasks. During the tasks the number of correct answers to shown stimuli, reaction times of these answers, the type of mistakes participants make, as well as recognition and usage or categorization rule could be an indicator of categorization strategies employed by participants. The main question of descriptive models is the definition of nature category-representation, with which we would be able to predict most accurately the results of category learning experiments. A feature of competing theories is that it adapts to the results obtained from experiments using the above mentioned methods in a sense that they try to explain every experimental phenomena. So, authors often change their models, so it could fit with the actual results.

The assumption that multiple memory systems underlie category-learning is a novel approach, which has modified the previous "power lines" with its appearance. The previous argument was about rule vs. prototype representation, now it has turned into the multiple systems vs. one system debacle. The other part of the previous debate remained, insofar that those standing for the one system approach mainly represent the prototype representation model.

The multiple memory systems' approach main representative COVIS (*Competition between Verbal and Implicit Systems*) model's starting point is the separation of two processes (Ashby et. al, 1998; Ashby & Waldron, 1999; Ashby et. al, 2011). The basis for the separation of two processes is the explanation of procedural effect observable in learning situations. A characteristic of this theory is that it defines the two systems using different tasks. These two tasks are the *rule-learning* and the *information-integration* situation. A characteristic of the rule-learning task that it contains an easily verbalized rule, since the categories separate along one dimension, where the diagnostic features' certain values are distributed between categories or corresponds to a simply definable, logically describable rule. According to the model the explicit processing-system governs rule-learning, by activating the working

memory and the executive system. During task-solving, participants continually execute hypothesis-testing.

The other task is the information-integration category-learning situation, where for successfully learning the integration of two or more stimuli-dimension is required. *Integration* can happen in a number of ways: it could be brought on by the holistic, Gestalt nature of stimuli, or the continuing attachment of stimuli features, their weighted combination as well. Despite participants still learn successfully in these situations, they are unable to simply define the rule by which they learnt (there are times when it is impossible, even). According to the COVIS model, this system is filogenetically older, and the procedural learning is controlled by implicit processes.

The main aim of the proposed experiment is to create an information-integration task by defining two categories using complex rules, of which discriminations the participants must learn. To do so, we created novel stimuli, all of which can be organised into a familiar similarity structure in regards to their similarity to the prototype. In the learning phase we gave the participants representatives of the categories, who encountered the specimen in a feedback learning task. In these tasks the degree and accuracy of category-learning is indicated by recognition of prototype and the conservation of graded structure. During learning a number of the specimen seen were showed in the test once again in a different form but with the same diagnostic values – this was done to test the preservation of prototype information.

In favour of understanding of background processes of categorization, we created a long-term visualisation task, where we conducted the test a week later as well.

Based on all this, the following hypotheses could be established:

Hypotheses

1. If we assume that the explicit and implicit systems work separately from each other, in the information-integration task the explicit, story based instructions won't have an influence on participants' performance.

2. In case of test-situation, if participants perform gradually worse according to typicality during specimen recognition, then the development of abstract prototype-representation should be detectable.

3. It supports the development of prototype representation if during the test participants perform better, if they encounter specimen similar to ones previously shown.

4. If we accept, that due to the influences of explicit, script like instructions, participants activate both systems, then during delayed recall we expect better results in the explicit condition from the participants.

The results were basically dual in nature. We couldn't detect the influence of explicit, story-based instructions. This can be interpreted as the participants learned the categories in both conditions. However, reaction time data hint at different background-mechanisms: The story instruction made the participants decisions faster (at the same time their performance did not lower). Based on this, we can assume that with the help of *explicit information we can successfully influence implicit processing mechanisms.* With the reaction time data we were unable to detect the influence of typicality. This could refer to participants using different strategies to solve the task.

The introduction of familiar specimen had no effect on the results here either. *Reaction times* changed, and in fact, contrary to expectations. Participants reacted slower in case of familiar stimuli. It is possible they have recognised the feature-structure, or that the specimen seen earlier did not look what they saw. In this case, we're talking about the development of a very effective prototype representation, which is able to compare the categorization rules with the prototype information as well. Creation of further studies could help testing these assumptions in the future.

The third part of our questions was the *long term preservation*. We investigated, whether category-knowledge can be preserved over long period of time. The result showed that in case of both conditions were successful in the repeated performance, if the participants did not decide category membership by randomly guessing. The prototype effect disappeared, however the lower hit rate observed before in case of bad specimen remained. Reaction times showed opposing tendencies here as well. The decision times of participant became shorter, meaning they made decision about category membership more confidently (and rather successfully) in the memory condition. The differences between the two conditions

(instructions) remain in this case as well, and the prototype effect appeared, in case of the story condition, in fact. In summary it can be said, that we were able to prove the basic assumption, that a basically implicit learning process can be influenced by activating an explicit system, if participants reaction times got faster while keeping the same hit rate. However these results did not bring us any closer to better understanding of the background mechanisms. We also can't give unambiguous answer to the assumptions regarding the preservation and utilization of prototypes. Similarly, the reaction times showed difference in this case as well, but the accurate interpretation of these is not possible in this study.

The question is, what happened in this study? Since perceptual category-learning situations usually involve simple set of points and other stimuli separated in a continuing dimension, and the models are based on these tasks as well, it is rather hard to interpret the data. The COVIS model, for example, doesn't explain accurately, what happens in case of complex stimuli.

A possible explanation is that with the story instructions we created an explicit condition from an implicit condition. In Johansen and Kruschke's (2002) experiment they used semantic bug like creatures, and found that the labelling of certain diagnostic features changes the specimen-information processing and causes the lessening of prototype effect. Naming of features pushed the results towards rule-learning. It could happen that in our case the story instruction directed participants' attention to the creatures' certain features. In this case, however, typicality effect could have been expected with the reaction times. It is also possible, though, that participants made one-dimensional decisions – but this does not explain the successful hit rates not differing from rule expectations. Gureckis and colleagues (in press) investigated the separation of implicit and explicit processes with fMRI. It's an interesting result, from our perspective, with an appeal for explicit processes they were able to cancel out implicit activity.

In so far as ourr situation, if we were able to, with the use of labeling and nesting into a story, truly make a complex rule base task's solution explicit, then the theories need to define the workings of implicit category-learning systems more accurately as well as the given functions range of activation tasks.

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